Monte Carlo Depletion

Bill Martin
Nuclear Engineering and Radiological Sciences
University of Michigan
Ann Arbor, MI 48109-2104
wrm@umich.edu

Preliminary comments

- **Monte Carlo depletion is a straightforward (in principle) extension of Monte Carlo methodology**
  - Need to include point depletion capability to the Monte Carlo code
  - Monte Carlo determines reaction rates
  - Reaction rates are used to determine cross sections for depletion equations
  - Solution of depletion equations determines number densities for next Monte Carlo step
- **Incorporation of point depletion capability**
  - **Explicit**: couple Monte Carlo code to independent point depletion code (e.g., CINDER or ORIGEN)
  - **Implicit**: incorporate point depletion capability directly within the Monte Carlo code (e.g., MCB)
  - Either approach is difficult in practice.

Monte Carlo “depletion” codes

- **MOCUP (1994) –** explicit depletion. Combines MCNP4 and ORIGEN2.
- **MCB (1999) –** implicit depletion. Based on MCNP4C. Continuous energy. Uses analytical solutions to linear chains (CINDER methodology) for point depletion analysis.
- **MCWO (1999) –** explicit depletion. Combines MCNP4 and ORIGEN2.
- **MONTEBURNS (1999) –** explicit depletion. Combines MCNP4C (or MCNP5) with ORIGEN2.
- **MCMG-BURN (2000) –** explicit depletion. Multigroup with WIMS macroscopic cross sections that are a function of depletion.
- **KENO-SCALE (2005) –** explicit depletion. Multigroup with ORIGEN-S.
- **MCNP5X (2006) –** explicit depletion. Combines MCNPX with CINDER90.

Caveat - this is not an exhaustive list of Monte Carlo depletion works. Several *ad hoc* Monte Carlo depletion calculations have been performed over the years but the above are named codes that couple Monte Carlo and point depletion.

Some Issues

- **Reaction cross sections.** Point depletion codes follow thousands of isotopes. Reaction cross sections are needed for all of these. These must be obtained from the Monte Carlo simulation or from built-in cross section sets in the depletion code. The latter may cause large errors and the former may lead to exorbitant computing times. A mix of the two approaches is usually taken – decide which isotopes should have cross sections determined by the Monte Carlo code versus a built-in library (e.g, 63 group CINDER90 library).
- **Fluctuations in reaction rates.** The Monte Carlo simulation must have sufficient histories to yield converged reaction rates.

The Real Issue – Fission Source Convergence

- The challenge with Monte Carlo depletion is the exorbitant computing time due to the slow convergence of the fission source for large, weakly-coupled reactor configurations.
- The need to do many timesteps and branch calculations off these timesteps causes the CPU times to grow rapidly.
- If we want Monte Carlo to be a useful design tool, and not just a benchmark tool, the issue of fission source convergence needs to be addressed.

Conclusions

- **We need to establish a goal to make Monte Carlo a tool for routine design/analysis of reactor configurations. We aren't there now but we need to move in that direction.**
- **Some essential/desirable features for a production Monte Carlo code for reactor analysis with depletion**
  - Generation of multigroup diffusion cross sections (including D's! and discontinuity factors)
  - Equilibrium xenon option
  - Lumped fission products – minimize Monte Carlo handling of all the isotopes followed by the point depletion code. Aggregate reactivity effect is important but not the individual isotopes.
  - Depletion in a critical configuration
  - Add capability to simulate decay heat deposition following shutdown. This would include all sources of decay heat as well as the transport of the neutrons and gammas.